I. Introduction

The Operational Oceanography and Meteorology (OC3570) class cruise for the summer quarter of 2002 was conducted aboard the *RV Point Sur* from July 15 to 22. The ship cruised along the California coast from San Lois Obispo, south to Santa Barbara, and then to San Clemente Island. My project will center on the rawinsonde data collected during the cruise, and it's relation to the cloud-bottom and cloud-top heights.

II. Purpose

The purpose of this report is to interpret the upper air sounding (rawinsonde) data that was collected; it's relation to the visual observation of the cloud-base height; and determines the cloud-top height from the sonde data. I chose to only study the low-level cloud observations (stratus and strato-cumulous clouds). The rawinsonde data is an important observational input to weather models, which would benefit from accurate cloud-top and cloud-bottom heights as well as cloud moisture content.

Theoretically, the rawinsonde data should record the height of (or pressure at) the cloud-base as the lowest point at which the air temperature and dew point are equal (100% relative humidity). Unfortunately this did not occur in these sondes. The cloud-base height can be measured by observing the height (or pressure) at which the balloon disappears into the cloud-base. This height will be compared to the sonde data.

For the same reasons, the rawinsonde data should record the height of the cloud-top as the highest point at which there is 100% relative humidity. Again, this did not occur in these sondes. The most interesting aspect of the cloud-top height data is that the upward leg of the sonde always depicts a greater or equal cloud-top height when compared to the downward leg.

III. Procedure

Over the coarse of the cruise, 24 rawinsondes were conducted. Of these, 14 were deemed to contain valid data and be relevant to my project. From this data I created plots of the temperature and dew point vs. height from the surface to 1300m for both the upward and downward legs of the sonde's flight (figures 1 - 14). The cloud-top height of the low-level clouds never exceeded 1200m. From this data set, the recorded pressure at which the balloon was observed disappearing into the cloud's bottom was correlated to the sonde's measured height and relative humidity. The maximum relative humidity and the height of the maximum relative humidity were found for comparison with the observed cloud-bottom relative humidity and height (figures 15 & 16).

After looking at the plots and relative humidities of the cloud-bottoms, a relative humidity threshold was picked for defining the cloud-tops. Using this threshold, a cloud-top height was determined for each upward and downward leg of the rawinsondes. The upward leg cloud-top heights were compared to the corresponding downward leg cloud-top heights (figures 17 & 18).

IV. Results

The relative humidity of the cloud-bottom averaged 94.5%, with a low of 91% and a high of 98%. The maximum relative humidity averaged 96%, with a low of 93% and a high of 99%. The maximum relative humidity was found to be ~1% higher than the observed cloud-bottom relative humidity. Surprisingly there were no readings of 100% relative humidity, and nearly 1/3 of the clouds never reached more than 95% relative humidity.

In order to define where the cloud-top was, I decided to use 91% relative humidity as a minimum. I chose this value because it was the lowest relative humidity of the observed cloud bottoms. For most of the sondes there is a sharp and obvious decrease in relative humidity just above the top of the cloud. However, my threshold choice created some problems in that there were five sondes that did not reach 91% relative humidity on their downward leg. The upward leg cloud-top heights were an average of 96m greater than the downward legs. None of the downward legs had a higher cloud-top height than their corresponding upward leg.

V. Conclusions

There are many possible reasons for the results that I have shown. Unfortunately, there isn't enough data to conclusively state that the reason 'X' was observed is due to 'Y'. This project leaves many unanswered questions.

There are some problems with the visual observation of the cloud-bottom height. Exactly when the white balloon disappears into a white cloud is difficult to see. Every person will see the balloon disappear at a different time. The other problem with the visual observation is the lag between when the observer sees the balloon disappear into the cloud and when the recorder reads the pressure from the sonde computer screen. These reasons take away from the precision of the visual cloud-bottom height.

The relative humidity values may be incorrect or biased for many reasons. I expected to see relative humidity values of 100%, but I did not. The humidity sensor on the sonde may have a dry bias, or the temperature sensor may have a warm bias, both of which would result in falsely low relative humidity values. It is also possible that a cloud can form when the relative humidity is as low as 91%.

The higher cloud-top heights of the upward leg have many possible causes. There may be sensor lag that causes the top of the cloud to appear higher on the way up and lower on the way down. There may also be errors caused by the wetting of the humidity sensor as it passes through the cloud resulting in a falsely high humidity reading after the sonde has passed out of the top of the cloud. It is also possible that the motion of the sonde through the cloud may entrain moist air as the balloon passes up through the cloud, and bring dry air down into the cloud as the sonde descends. Another possible error inducer could be the loss of the humidity sensor's protective cap on some of the sondes.

The issue that I believe may cause the greatest error is that the sondes do not rise and fall at the same location. As the balloon rises and falls, it is at the mercy of the winds. The 'Up/Down' sondes with the syringe and 7/32 inch hole, were airborne for ~30 min and reached a height of ~2800m. The sondes without the syringe were airborne for more than two hours and reached heights of greater than 15,000m. It would have been interesting to track where the sondes rose and fell, but the latitude and longitude were only recorded at the release point (in the provided m file). I'm sure that the positional data is available, but I didn't have access to it. Analysis of the balloon's motion may explain the cloud-top height differences that were observed.

To summarize, our data showed that the bottom of clouds (as determined by where we lost sight of the balloon) have an average relative humidity of 94.5% and the cloud's maximum relative humidity is ~1% higher than it's cloud-bottom relative humidity. These values are less than I expected and may be due to sensor errors. Our data also showed that the upward leg of the sonde depicted a higher cloud-top than the downward leg, and some of the downward legs never met my threshold for cloud relative humidity. I have proposed many possible explanations for these observations. This is an area that could benefit from further study.